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ABSTRACT

This paper demonstrates an approach which enables one to reduce in a systematic way the immense complexity of a large body of knowledge. This approach provides considerable insight into what is known and unknown in a given academic field by systematically and pragmatically ordering the information. As a case study, the authors selected approximately 1200 titles from the Engineering Branch Library at the University of California at Berkeley whose face validity suggested application to the interests of cybernetic systems personnel. They developed a hierarchic methodology (a structure consisting of four levels--theoretical systems, mechanics, control, and information--in which the first level is the most basic echelon and the remaining three are encompassed by the ideas found in the first level) to promote inductive investigation and retrieval from this aggregate of varied titles. The authors discuss the results of their experiment using this structure and the implications for solving complex problems involving large bodies of knowledge through use of this hierarchic methodology. (LG)

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A HIERARCHIC SYSTEM FOR INFORMATION USAGE

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We picture an aggregation of knowledge as having a finite set of principles with a fluid structure. A set of decision rules which operate with these principles allow and encourage production of new knowledge and applications of the knowledge. This paper will demonstrate an approach which may enable one to reduce in a systemic way, the immense complexity of a large body of knowledge. In addition, this approach may provide considerable insight into what is known and unknown in a given academic field. In a developing area such as Cybernetic Systems or Behavioral Communication there is much that can be explored, but there exists no specific methodology which attempts to systemically and pragmatically order the documents. As a case study, we selected approximately twelve hundred (1200) titles from the Engineering Branch Library at U. C. Berkeley whose face validity suggested application to the interests of Cybernetic Systems personnel. We developed the following methodology to promote inductive investigation and retrieval with this aggregate of varied titles.

From Angyal's (1941) seminal work we identified three logical genera: aggregates, wholes, and systems. We consider that forms of hierarchy may be the appropriate decision rules which allow consideration of an aggregate as a system. By decision rule, we specifically mean rules of choice for structuring masses of titles as a system. A system, for our purposes here, is defined as an entity which can be visualized to contain an input, an interface, and an output. Other sources of decision rules may be derived from automatic control, multivariate analysis and operational research tools, but we feel these rules of decision would be inappropriate for knowledge systems.

Let us first consider the "parts" or "data" from which we attempted to draw the finite set of principles which joins our aggregation of knowledge. We use as our notion of levels Mesarovic, Macko, and Takahara's (1970) conception of "strata," the level of description or embedding, "layers," the level of decision or affiliation, and "echelons," the organizational or coordination level. There is no unique correspondence among layers, strata, and echelons. Tasks for more than one echelon can be defined by using the ectype from the dominant stratum, while echelon decisions must include the ectypes from the echelons, at least, above and below the given stratum. Decisional or control statements must involve an operation of system relationships among the triad of layers, strata, and echelons.

We suggest the process of building strata can take place when the following sequence of conditions are successively met. (S_0) There exists an object of concern. (S_1) All relations or descriptions of the object of concern are each a member of a class of relations or descriptions which can be applied to at least one other object of concern. (S_2) A synthetic class consisting of relations as elements is formed such that affiliation constituents can be visualized. (S_3) The resultant class must be documented such that personal validation can be effected upon that creation.

In the instance of (S_1) we refer specifically to the section of Feibleman and Friend's (1945) work entitled "Elements of Relations." He cites transitivity, connexity, symmetry, seriality, correlation, association, distribution, addition, multiplication, and dependence as examples of relations. Each one satisfies the "class of relations" requirement of condition (S_1). Examples of descriptions which belong to (S_1) are spatial, temporal, spatio-temporal, logical, arithmetical,

variational, and perhaps hierarchical descriptions. Relations allow embedding and thus hierarchic expansion, whereas descriptions are a lateral expansion which bounds an affiliation constituent on any one strata. Lateral specification demands vertical embedding for an understanding such that the condition of (S_3) can be produced.

The process of building layers has a process similar to that used for building strata. This process is governed by a hierarchy of rules where each layer contains sets of rules. (D_1) Each rule within a layer contains a trinity of strata which can be labelled Rule, Strategy, and Tactic. See Schützenberger (1954). (D_2) Supraceding layers reduce the number of alternative rules in each recessive layer. (D_3) Temporary closure or completion of one "feedback" loop can be documented or validated to determine a trinity of Rule, Strategy, and Tactic. This design has been called a supremal decision problem by Mesarovic, Macko, and Takahara (1970). Another similar conceptualization is the term "taxonomy." It is in this manner that the "uncertainties of decision-making or "affiliating a synthetic set of possibilities" is reduced. For example, Weick's (1969) "levels of equivocality" theory constitutes the Rule whose Strategies are interlocked behaviors, and whose Tactics are the respective behaviors.

Echelons are the scheme and framework whereby aggregates of strata and layers are coordinated. Given the above, we can consider the process of organizing to be characterized by progressions from one echelon of coordination to another. Once again, in a sense similar to strata and layer progression, we now attempt to specify a set of statements which apply in each case where there is progress from one echelon to another. We first state recognition criteria; ones which must be apparent before any consideration of process rules of echelon may be entertained. ($c0_1$) If an echelon statement with string structure subject-verb-object (svo) is issued by one affiliation constitutent to another, and that same statement can be replaced by a statement of string structure "svo"-verb-object, then we can say that the former affiliation constituent asserts echelon dominance on the latter. This principle is a process of compaction. ($c0_2$) The replacement of the "subject" in ($c0_1$) by the entire statement "subject-verb-object" is a reduction of representation without reduction in content in each instance where the echelon statement is placed within the same affiliation context that specified the document of strata (S_3).

With the recognition of conditions ($c0_1$) and ($c0_2$), we can now state an echelon progression law. (0) Coordination is effected by the application of strata principles on echelon statements. Note that the strata principles require a visualization of affiliation constituents. As such, we can now see many hierarchies of layers on a flat surface. The echelon statements captures the relations among affiliation constituents. Strata principles operate on these relations, which we have called echelon statements.

Having presented the principles, let us now specify a list of problem areas which allow us to speculate on reducing the complexity of a large body of knowledge to manageable proportions. 1. The problem of integrating particular statements (titles which categorize contents) and echelon statements which identify an academic field. 2. The problem of proximity and thus the usage of relational ties of (S_1). 3. The problem of producing mechanisms for the control of knowledge-acquirer; material irrelevance conflict. 4. The problem of particular statements (titles) being applicable in view of changing echelon conditions ($c0_1$-$c0_2$-0). 5. The problem of aiding in constructing

systems which clarify and assert the identity of the aggregation of knowledge.
6. The problem of providing means for eliminating outdated material.

We now turn to applying these hierarchic principles to our 1200 titles. Any title serves as an initial point. If any additional titles was related to the initial title through some intuitive or aesthetic judgment, this second title would then be placed in the same group as the initial title. Unrelated titles initiated new categories. If any category consisting of two or more titles was subsumed under another category, the two categories would be placed adjacent to each other in order that the next stage of arrangement be easily executed.

Drawing an analogy to the card game Concentration, we find a similar process. It does however, have two complications. There are two or more decks of cards which implies that triples, quadruples, or n-tuples of cards can be combined. These different cards from different decks cost different amounts of money and the rule of the game is to place the most expensive cards on top of the three, four, five, or n level stack. The parallels between the two sorting processes are: titles are used as cards. Relations between cards are categories and the dollar cost ranking of the decks show the "adjacent" phenomenon. In this manner, twenty-eight categories were assigned to the aggregate of titles. The list of these categories are in Appendix II.

Following this categorical ordering, an ordering of the titles within the categories was done using the following criterion. The combination of titles which would establish some framework for thoughts in that area. Within this combination, there should be examples of existing works in the field, and which, perhaps provides problem areas which might yield interesting conclusions if approached from that vantage.

Such a combination can be seen in the second subcategory of "Historical Foundations and Topics of Current Concern." The sub-category entitled "communication and transport." The sequence: International Federation for Information Processing; A Working Conference on "Symbol Manipulation Languages and Techniques" provides an example of an existing work in the field. The succeeding titles "Bracketed Grammars, Language and Information; Theory of Syntax; Technological Forecasting in Perspective; its techniques and organization" provides both examples of theoretical works related to information processing and a problem area. First, Technological Forecasting which might yield interesting conclusions if one considers that the methodology of analysis exemplified in the theory of language statements are applicable to technological forecasting. Secondly, a consideration of the past as information to be processed by man provides interesting material for discussion. The sequential organization of categories was arranged with the same criterion. In cases of subcategories within categories, this procedure was followed once more. See Appendix I.

To further integrate the titles, an attempt was made to provide a holistic structure where categories would be free to associate with other categories such that some portion of this whole would be the basis for an extension such as a paper; a paper using titles within those categories as references. This extension should also be apparent within the physical appearance of the structure. Trends of categories should be readily visible.

The development of such a structure was done in two steps. The first was an attempt at preserving a sequential structure with the title 'hierarchy' as the basic unit. All other topics were arranged at its periphery with the

two ends of the sequence being "mechanics" and "the philosophical aspects of hierarchy." We found network lines would have to be drawn between related peripheral categories. This was not aesthetically appealing. On examining this initial diagram, it was noted that four central topics dominated the sequence. Using these four, a multi-level structure was created. The four levels were "theoretical systems" on level one, "mechanics" on level two, "control" on level three, and "information" on level four. We located level one as the most basic echelon. The remaining three should be encompassed by the ideas found in level one.

With this scheme, peripheral topics were free to be associated with one level as well as another by virtue of its position in the whole. It also allows one to see "little bodies of knowledge" within the context of this whole. Interlevel waves of ideas can be seen in both the sequential pattern which floats from level to level and the pulse-like shape starting at "theoretical systems," peaking at "theoretical and human organizations," and tapering at "systems engineering" and "information." This same pulse can be seen in the spectrum from "mechanics" to "control." This scheme is designed to be an observable object which acts as a catalyst in spurring thoughts whose sequence is hierarchic in constituency.

Having described the structure and having documented a sizeable experiment with the use of this structure, it is now time to play a futurist game to decide on the usefulness of analysis such as this. The future of this structure lies in its real world counterpart which is coming, but is not yet realized. The reality of techno-structures whose unified function has been shadowed by their teams of specialists would probably benefit from the use of this hierarchic methodology to coordinate the respective bodies of knowledge. By coordination of the strata inherent in the specialties, through the use of echelon principles, we would hope that a body of knowledge, physically realized can constitute ad hoc interdisciplinary groups which are thrown together to solve complex problems. It is in this sense that this methodology can be applied to integrate modes of thought. Some people are more adept at thinking by analogy. Some by appropriate use of "NOT." (e.g. Existing conditions are not conducive to. . .such and such is needed on the basis of. . .) Some people operate best on problems where data gathering has been completed. By repeated application of hierarchy, even the most complex problem can be reduced to "general" supremal problems which can be dealt with by groups specializing in their respective modes of thought. Referring back to principles, one can see that this encompasses the title "interdisciplinary."

APPENDIX I

The Sequential Organization of Categories

"Theoretical systems" (1) provides readings which is the basis for organizing systems. "Techniques, technology and the basis for hierarchy" (2) is also a base. It provides the framework for the methodology and mode of thought named hierarchy. "Theory of information communication" (3) provides information on current endeavors in communications. Together, (2), and (3) constitute a system. With both (1) and (2) in mind, one can ask if theoretical systems encompasses such a system. And if so, does this entail unforeseen details in (2) and (3)? Similarly, does (2) and (3) offer new insights into the nature of systems? With "toward the development of systems of information" (4) one can ask if there are units which allow categorization of systemic material. Is there a "system" of information? "The structure of information pools" (5) provides material on current efforts in the storage of information and offers material which may lead to new methods of information storage. This is one mode of (4). "Information, its structure and development" (6) is a category fully devoted toward exploring alternative bases from which, one can develop (4) and (5). "Mathematical aspects of control" (7) show currently known efforts at organizing information such that some parameters of a situation may be manipulated for alteration of the initial state of information. "Adaptive and optimal control" (8) shows current efforts at providing schemes for narrowing the choice of parameters such that goals may be achieved more quickly, or with a smaller disturbance from the equilibrium of the situation. "Transport, the basis for hierarchic travel (9) is an example of past works in atomic and molecular motions." "Practical aspects of information communication" (10) presents material that can be combined with essences distilled from (9). This combination would be a base for examining "psychological factors, barriers and paths to reception" (11). By integrating (9), (10) and (11), one can examine parallels between "human and mathematical modes of communication" (12). By use of (12) and (1 through 11), perhaps one can add to the category entitled "toward the development of social metrics" (13). Aiding further in this effort is the category "man and environment" (14). This category includes a multiplex of subcategories such as artificial intelligence, intra-cranial blood flows, technological cybernetics, and communication in a seemingly random environment. Combining the theoretical systems, information, and people categories, one may ask how one can further one's understanding of "philosophical aspects of hierarchy" (15). How does one relate systems (1) to the techniques of control (7, 8)

What does this have to say about the technosocial interface? Do the people categories reinforce the distinction between technical and social endeavors? Is social psychology a new field which attempts to bridge this gap? Are readings in organizational development (not mentioned in the list of titles) attempts at controlling this gap between technical and social endeavors? How is this reflected in policy planning procedures of inventory control, production scheduling, and other particulars of "business, managerial" (16)? By looking at "historical foundations and topics of current concern" (17), one can examine a history of attitudes and be observant of trends which led to current concerns in urban transport and traffic control, government and society, pollution, modeling and simulation, numbers, and the methodology and structure of decision making. In suggesting that the methodology and structure of decision making is a trend to be explored in the future, a separate category of present examples is given in "decisions and queues" (18). Developments from (17) and (18) would be

interesting to explore. Toward this end, "mechanics" (19) is provided as a possible framework for structuring (18). Strictly as a local concern, "thermodynamics" (20) is presented as an adjunct to mechanics primarily because thermodynamics is associated with mechanical engineers. Furthermore, since thermodynamics includes the topic entropy, and inverse entropy has been used to describe information, this category is presented in order that the original uses and the operational definition of entropy be more carefully considered in its application as "inverse."

Item (19) is presented such that the reader can re-examine concepts of information found from earlier categories on information. For the reader who has more than a passing acquaintance with mechanics, "mechanics, presented in the spirit of Newton's Mathematical Principles of Natural Philosophy" (21) is given in the hopes that these works will spur further thoughts that develop into principal statements useful toward the development of systems. In the same sense as the last statement, all the categories (1 through 21) may be used to develop alternatives to present structures of "organizations" such as bureaucracy, theocracy, monarchy, oligopoly and others. To illustrate inter"personal" communication within structures, and between proactive stores of information, "Games" (23) is presented. Returning to "historical foundations and topics of current concern," we find "systems, social commentary" (24). This is presented as an example of descriptions which may be applicable to whatever develops from the categories on mechanics, (19) through (21). "Systems engineering" (25) provides examples of how an organization can be proactive. "Operations research" (26) is an even more specialized example of inter"personal" communication. "Systems practical" (27) provides examples which can be used to reinforce or defeat thoughts gained from organizations, games, decisions, systems, and all the other categories by means of category (1) theoretical systems. "Alternative Reference Sources" (28) provides other sources of storage different from this entire series, (1) through (28).

APPENDIX II

A Sequential List of Categorical Titles[1]
(Sequence number, level)

1,1 Theoretical Systems.
2,1 Techniques, Technology, and the Basis for Hierarchy.
3,4 Theory of Information Communication.
4,4 Toward the Development of Systems of Information Organization.
5,3 The Structure of Information Pools. (Storage)
6,2 Information, its Structure and Development.
7,3 Mathematical Aspects of Control.
8,3 Adaptive and Optimal Control.
9,2 Transport, the Basis for Hierarchy.
10,4 Practical Aspects of Information Communication.
11,2 Psychological Factors, Barriers and Paths to Reception.
12,3 Human and Mathematical Modes of Communication.
13,2 Toward the Development of Social Metrics.
14,2 Man and his Environment.
- (a) The Universe and Life Phenomena,
- (b) On Self-Organization in Machines,
- (c) Human Organizations,
- (d) Natural Decision-Making within People,
- (e) Artificial Intelligence,
- (f) The Mechanics of Limbs and Fire,
- (g) Sight and Sound,
- (h) Intracranial Blood Flows,
- (i) Man-Machine Interaction,
- (j) Bioengineering,
- (k) Measures of Performance,
- (l) Technological Cybernetics,
- (m) Communication in a Seemingly Random Environment.

15,1 Philosophical Aspects of Hierarchy, The Qualitative, Quantitative Boundary.
- (a) Systems,
- (b) The Techno-Social Boundary.

16,4 Business, Managerial.
17,2 Historical Foundations and Topics of Current Concern.
- (a) A History of Attitudes,
- (b) Communication and Transport,
- (c) Urban Transport and Traffic,
- (d) Government and Society,
- (e) Pollution,
- (f) Modeling, Simulation and Numbers,
- (g) Methodology and Structures of Decision Making.

18,3 Decisions and Queues.
19,2 Mechanics.
20,2 Thermodynamics.
21,2 Mechanics presented in the Spirit of Newton's Principia.
22,4 Organizations.
23,4 Games.
24,3 Systems, Social Commentary.
25,4 Systems Engineering.
26,3 Operations Research.
27,3 Systems, Practical.
28,3 Alternative Reference Sources.

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[1] A complete bibliography may be secured by writing the authors at the Speech-Communication Department, California State University, San Jose, California 95114.

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Acetate Level 1

Theoretical Systems 1

Techniques, Technology 2
and the Basis for Hierarchy

Philosophical Aspects of
Hierarchy, The Qualitative,
Quantitative Boundary 15

Alternative Reference
Sources 28

Acetate Level 2

Barriers and Paths to Perception; Psychological Factors 11

Toward the development of social metrics 13

Transport, The basis for hierarchic travel 9

Man and his Environment 14

Mechanics 19

Information, its structure and development 6

Topics presented in the spirit of Newton's Principia 21

Thermodynamics 22

Historical Foundations and topics of current concern 17

Acetate Level 3

Mathematical Aspects of Control 7

Control, Adaptive and Optimal 8

The Structure of Information Pools 5

Decisions and Queues 18

Operations Research 26

Mathematical and Human Communication 12 (Languages and Machine Languages)

Systems, Practical 27

Systems, Social Commentary 24

Acetate Level 4

ames 23

Theoretical and Human
Organizations 22

Toward the Development
of Systems of 4
Information Organization

Business, Managerial 16

Systems Engineering 25

Practical Aspects of
Information Communication 10

Theory of Information Communication 3